5888-EN-01

1

AD-A229 219

IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE
Exhibition Road, London SW7 2BX.

Final Report to U.S. Army

Department of the Army
U.S. Army Research,Development & Standardization Group (UK)

DTIC
S ELECTE NOV 16 1990 D
B

IN-CYLINDER PROJECTILES

Contract No: DAJA 45-87-C-0045
(5888-AN-01)

DTIC FILE COPY

by

J.H. Whitelaw

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

August 1990

Summary of research program

Research has been conducted at Imperial College with three gun simulators which represent a progression towards real guns, with continuing emphasis on the improvement of understanding of fluid mechanics and heat transfer. The first and second simulators made use of 75mm diameter barrels with muzzle velocities up to 50m/s and the third, designed with the experience of the first simulator with existing instrumentation prior to the present contractual period, and the results have been reported by Bicen, Kliafis and Whitelaw (1986) and Khezzar (1987).

The second simulator incorporated many improvements including the method of securing and releasing the projectile and the replacement of the mechanical method of measuring projectile position, with associated friction, by an optical method. In addition, single-phase velocities were compared with the velocities of solid particles (40μm in diameter) arranged to simulate propellant particles and wall temperature was measured as a function of time and axial position. The results of those investigations are recorded in the Doctorate theses of Khezzar (1987) and Schmidt (1989) and by Bicen, Khezzar and Whitelaw (1988) and Bicen, Schmidt and Whitelaw (1990). In general, they quantify the increase in projectile velocity and the deviations of the gas and particle velocities from each other and from the projectile. The gas expansion was shown to be close to isentropic and the wall temperature to rise immediately after the passage of the projectile with subsequent decay towards values corresponding to the heat-transfer coefficient of developed pipe flow. Emphasis was placed on the near-wall region and confirmed the turbulent nature of the unsteady boundary layer.

The third simulator, like the first two, was designed mainly by Dr A. Bicen with the added requirement of allowing gas and projectile velocities which approached those of the simulators used at the Ernst Mach Institute, thereby providing a spectrum of investigations encompassing lower gas-guns velocities at Imperial College, moderate gas-gun velocities at the Ernst Mach Institute and real guns at the Aberdeen Proving Ground. This spectrum was, and is, intended to provide understanding in a progressive manner with greatest detail of measurement and related understanding at the lower velocities with which measurements are easier to make with high accuracy. At the same time, this philosophy facilitates the development of calculation methods, based on the numerical solution of conservation equations in differential form, as currently in progress at the Ernst Mach Institute with Army support.

per form 50
A-1

With these requirements in mind, the third simulator was designed and developed to encompass initial gas pressures up to 60 bars and maximum projectile velocities up to 500m/s. Effort was required to find the correct projectile material so as to avoid problems of wear while retaining low friction and gas leakage, and the system was automated to allow easy return of the projectile for each shot. Also the projectile release mechanism was redesigned and required development. The main emphasis, however, was on the design, arrangement and improvement of instrumentation. In this case, pressure, wall temperature and velocity signals were communicated through an interface to a microcomputer (IBM/AT) with direct memory access and with time response around 40μm compared to the 8ms of the duration of the fastest shot. The laser-velocimeter system was different from that used previously, particularly in that a fast counter was required. Similarly, new thin-film thermocouples were required to deal with the much faster response times.

The extensive results obtained with the third simulate are recorded in the Doctorate thesis of Schmidt (1989) and in the Masters thesis of Perez-Ortiz (1989). The various papers of Bicen, Schmidt and Whitelaw (1990) and Bicen, Laker, Schmidt and Whitelaw (1989) provide further information. As with the previous investigations, the results are provided in sufficient detail to aid the development of calculation methods. The trends are similar to those of the results at lower pressures and velocities. The near-isentropic nature of the expansion was retained, the consequences of some blow back of gas was noted in the temperature measurements as was the very rapid increase in temperature after passage of the projectile followed by an initially very rapid decay.

Communication and Personnel

The research was carried out in close harmony with related experiments and calculations at the Aberdeen Proving Ground and at the Ernst Mach Institute. Related workshops were held at Weil-am-Rhine and Imperial College, with additional meetings between the staff of the two establishments occurring twice each year. In addition, visits were made to the Aberdeen Proving Ground at least twice each year for discussions with Dr C. Zoltani and Dr G. Keller, and regular contact was maintained with Dr F. Oertel and Dr R. Reichenbach of the European Research Office.

The work at Imperial College was carried out mainly by three graduate students, Dr L. Khezzar, Dr M. Schmidt and Miss R. Perez-Ortiz. Dr Schmidt was supported by the Contract and has returned to the United States to take up a Research Fellowship at the

Aberdeen Proving Ground. The design of the three simulators was undertaken mainly by Dr A. Bicen and Mr J. Laker provided the electronic developments; both were employees of Imperial College and not supported by the Contract. Similarly, all instrumentation was made available to this work by Imperial College to a total value in excess of $300,000, with the Contract meeting the cost of maintenance and small components. Thus, the contract facilitated the conduct of the research, with more than matching support from alternative sources.

Achievements

The following sentences provide an indication of some of the achievements of the research.

- Evidence of the turbulent nature of the unsteady boundary layer along the barrel of the low-speed simulators and the provision of pressure and velocity data used at the Ernst Mach Institute in their development of a calculation method.

- Confirmation of the near-isentropic nature of the gas expansion in the second and third simulators with the largest deviation less than 4% of local measurements.

- Quantification of the extent to which 40μm solid particles initially lag and subsequently lead the gas flow in the second simulator and provision of evidence to support clustering of particles with terminal velocity related to the cluster.

- Development of a facility, including related instrumentation, for the on-line measurement of pressure, velocity and wall temperature, to allow investigation of these characteristics at velocities up to 500m/s.

- Provision of accurate and detailed measurements of pressure, projectile velocity, gas velocity and wall temperature with an initial pressure of 10 bars and projectile velocities up to 200 m/s and documentation in a form which allows convenient comparison with calculated results.

- Evidence of slight blow-back of gas with consequent increase in wall temperature in front of the projectile; quantification of the rapid temperature increase immediately after the projectile and analysis of results in terms of heat flow and heat-transfer coefficient.

. Training of two Doctorate and one Masters student and award of Fellowship which allowed Dr Schmidt to conduct research at the Aberdeen Proving Ground.

Recommendations

Methods of measuring particle size and temperature of burning propellant should be investigated in the context of the third simulator. It is expected that an arrangement of a laser velocimeter with calibration of amplitude of Doppler signal against particle size will meet the first requirement and two-colour pyrometry the second.

The research should be extended to include propellants so that a combination of pressurised gas and propellant material are used to drive the projectile. The proportion of propellant should be increased to determine the value beyond which optical measurement cannot be obtained in the third simulator and the consequences of the propellant for measurements of wall temperature determined.

The present measurements should than be extended to include the size and temperature of the propellant and the results used, together with a closely related calculation effort, to predict the properties of gun flow so as to allow the prior determination of the influences of breach and projectile geometry and of the nature of the propellant charge.

References

A. Bicen, L. Khezzar and J.H. Whitelaw (1988)
Subsonic single-phase flow in a gun simulator. AIAAJ 26, 47.

A. Bicen, L. Kliafis and J.H. Whitelaw (1986)
In-bare velocity measurements in the wake of a subsonic projectile. AIAAJ 24, 6.

A. Bicen, M. Schmidt and J.H. Whitelaw (1990) Heat transfer measuremntes in inert single and two-phase flows in a subsonic gun simulator. To be published in J. Exp. Heat Transfer.

A. Bicen, J. Laker, M. Schmidt and J.H. Whitelaw (1989) Instrumentation for transient gas velocity, pressure and heat flux measurements in a gun simulator. Proc. 13th Int. Congress on Instrumentation in Aerospace Simulation Facilities, Gottingen.

L. Khezzar (1987) Experiments with steady and unsteady confined turbulent flows. Ph.D. Thesis, University of London

R. Perez-Ortiz (1990) Wall heat transfer measurements in a simulation of a gun barrel flow. M.Sc. Thesis, University of London

M. Schmidt (1989) Flow in curved ducts and gun simulators. Ph.D. Thesis, University of London